PEER REVIEW

Monitoring Vegetation Changes in Historical Photos over a 45+ Year Period in the Adirondack Alpine Zone

By JULIA GOREN and CHRISTOPHER MONZ

A contemporary image analysis procedure was used to analyze historical and contemporary images taken from designated photo monitoring points on alpine summits in the High Peaks Region of New York State. Oblique images were analyzed for comparative changes in various groundcover classes across time periods ranging from ten to over 45 years. Although purposive in nature, study findings suggest an overall trend of maintaining or increasing vegetation cover in association with summit locations where a long-term visitor education program that emphasizes avoiding alpine vegetation has been applied.

Introduction

Despite the small geographical area that they compose, alpine zones are disproportionately important within the Northeastern United States. These areas, which include Mt. Katadhin in Maine, the Presidential Range in New Hampshire, Mt. Mansfield in Vermont, and the Adirondack High Peaks in New York State, are both biologically rich and of significant recreational value. Due to an exceptionally high visitor demand, these areas epitomize the dual challenge of providing recreation experiences and protecting fragile resources (Monz et al., 2010).

Within the Adirondack High Peaks, the alpine zone is one such area; ecologically rare, fragile, and under high demand for outdoor recreation activities. A remnant of the last glaciers and comprising 70 hectares spread over several mountain summits, the Adirondack alpine zone is one of the most heavily used alpine areas in the northeastern US (Howard, 2009). Some 27 rare, threatened, or endangered vascular plants are found in this unique ecosystem (Young and Weldy, 2006). While these alpine species are able to tolerate the difficult growing conditions of the mountain summits, additional stress caused by hiker trampling damages the vegetation, allowing soil erosion to occur (Ketchledge et al., 1985). This damage inflicted upon fragile alpine vegetation and soils has been well documented in other alpine areas throughout the Northern Forest of the Northeast US (Doucette et al., 1989; Goonan, 2009; Monz et al., 2010).

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Monitoring the condition of resources, particularly those in remote, alpine locations, is a perennial challenge for park and protected area managers. In addition to the technical aspects of determining indicators and accurate measurement protocols, managers often face significant limitations on the financial and personnel resources required to carry out field data collection and subsequent data analysis (Leung and Monz, 2006). Long-term monitoring is particularly challenging as personnel change over time, potentially compromising the accuracy and precision of field methods and trend analyses. As a result, many natural areas have little data on which to base management decisions. A recent examination of resource monitoring data across the US National Wilderness Preservation System suggests that approximately half of the over 600 wilderness areas have no baseline data (Cole and Wright, 2003). As such, there remains an interest in continuing to enhance the ability of monitoring efforts to be accurate, precise, and consistent while minimizing the time and effort required collecting these important data.

This paper reports on an innovative analysis approach that examined historical and contemporary photos taken at designated monitoring points in the Adirondack alpine zone. Overall, the project had two goals; first, to determine whether trends in vegetation change were occurring over time at the monitoring locations and second to determine if recent visitor management efforts by the Summit Steward Program to minimize vegetation damage were effective in minimizing vegetation loss at these locations. We emphasize that this study is limited in the ability to generalize the findings due to the purposive nature of the photo monitoring points. Nonetheless the data are valuable and provide an important historical context. In addition to the examination of these important resource condition trends and their management implications, the image analysis approach developed in this study is an important innovation which could be applied in many other situations where managers have photos taken over time with little quantitative data.

Background and Methods

The Adirondack High Peaks Summit Steward Program was created in 1989 to replace prior management efforts that were insufficient to protect rare species from trampling due to off trail hiking (Figure 1). The Summit Steward program is a partnership of the Adirondack Mountain Club, the Adirondack Chapter of The Nature Conservancy, and the New York State Department of Environmental Conservation. Stewards interact with the recreating public on the highest summits; they also complete conservation projects to ameliorate erosion, delineate trails, and participate in research (Figure 2). Since the program's inception, stewards have spoken with over 307,000 hikers in the alpine zone (Goren, 2011).

Figure 1. Summit Stewards educate the hiking public about fragile alpine vegetation.

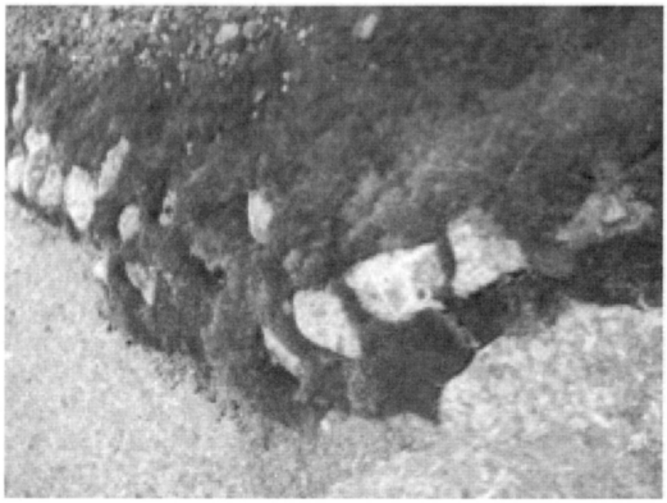

Figure 2. A scree wall, built by summit stewards to stabilize loose soil, has been enveloped in moss over time.

The Summit Steward photopoint monitoring project was established in 1999 and has been engaged in long-term monitoring of areas subject to recreation use (Scott, 1999). The photopoint monitoring system was based on historical photographs ranging in age from five to over 45 years (Scott, 1999). In 1999, historical positions were relocated and photographs were re-taken. Descriptions of camera height, angle, direction, and other attributes were recorded, making the establishment of consistent photopoints a possibility. Camera tripod locations were marked in the field with a small nail drilled into the bedrock and compass directions were recorded. Each photopoint was assigned a retake cycle based on severity of disturbance, location, and ecological significance (Scott, 1999).

The analysis of close range photos for monitoring the conditions and trends of natural resources using contemporary image analysis procedures is an emergent technique that continues to show significant promise in recreation impact monitoring. Recent development of these techniques in rangelands to determine vegetation cover (Bennett et al., 2000; Booth et al., 2004, 2005) have found favorable comparisons with point frame methods and increased field efficiency. In particular, image analysis has been shown to facilitate greater data collection due to ease and efficiency in the field, to be superior for determining relative change over time, and useful for providing a permanent visual record of plots for future analysis (Booth et al., 2005). More recently these techniques have been applied and tested in recreation impact situations, both in monitoring campsites (Monz and D'Luhosch, 2010), and on vegetation conditions on mountain summits (Monz et al., 2010; Goonan, 2009).

Digitized historic and current photos were assessed for location and color accuracy, adjusted, and edited using Adobe Photoshop. Photo analysis was performed using custom software and analysis procedures initially developed for the assessment of close range nadir images in rangelands (Booth et al., 2006) and adapted to monitor recreation resource conditions on Northern Forest mountain summits (Monz et al., 2010). This procedure uses SamplePoint software and has the capability of resolving groundcover classes into vegetation types (e.g., grasses, forbs, shrubs, lichens, etc.), mineral and organic soil, bare rock and other classes as needed. Historic (film) photos were scanned and compared to current photos using standard digital photo editing techniques. This process also allowed for slight adjustments in photo alignment.

SamplePoint software operates by superimposing an ordered grid with a random start point on the image to be analyzed. The points become locations for an evaluator to make decisions as to what groundcover type is located at that pinpoint on the image. As such, the process is not an automated image analysis procedure as is possible with other software, but affords the ability to classify groundcover groups generally more difficult to separate in automated procedures. SamplePoint is similar to small plot "pin frame" methods that have been used for decades and has the advantage of not having to be performed in the field.

While there is little that can be adjusted in the operation of SamplePoint, several factors were considered. These were evaluated at the onset of working with the images in this data set. First, overall image quality can affect the ability to determine specific groundcover classes at an intersection point. To address this, we examined a range of photos from early scanned images to modern digital images to assure that adequate detail was available. Second, the number of points per image can be adjusted (i.e., a 10 × 10 grid, 9 × 9 and so forth). Given the variation in these images and that some contained vegetation and soils only in part of the image due to their oblique nature, we decided on 100 points per image to assure accuracy. Last, it is important to note that the images are all oblique in nature and therefore do not deliver the same kind of data possible from a nadir image, i.e., vegetation cover is only meaningful when compared from similar images over time, not as an absolute measure.

On summits without a consistent stewardship presence, trends point to slight decreases in overall vegetation cover, while on remote summits, with low visitation, trends suggest an increase in vegetation.

In total, the Summit Steward program has 222 photographs from 50 photopoint locations spread over 9 summits. A subset of 119 photographs was used for this project. Photopoint photographs include off trail and trailside areas, but focus on the trailside areas; most depict areas of human impact in some area of the photograph (see Appendix for example photographs). All photos were classified into the following groundcover classes: grasses, forbs, lichens, mosses, shrubs, krummholz, trees, mineral soil, organic soil, exposed rock, and gravel. In general the classification was accomplished with little difficulty, although the older film images required extra time due to the lower resolution of these scans.

Statistical tests were performed using SPSS Statistical Software (v. 19, SPSS, Inc, Chicago, IL) in various analyses as dictated by the repeated design and available data. We approached the analysis of the continued monitoring of established photopoints in two ways; first as a repeated measures design where identical images were taken over multiple time intervals. Data extracted from these images was analyzed with time and summit location as factors in the repeated measures ANOVA. Repeated measures tests and associated descriptive statistics were performed in two separate analyses as dictated by the available data. The first analysis examined photopoints where three time periods could be assessed; the second analysis examined photopoints where only data from 1999 to 2009 are available. In our second analysis approach we examined basic descriptive statistics of trends in overall vegetation cover on individual mountain summits organized by the level of Summit Steward involvement.

Results

The first analysis spanned available data over three time periods from the 1960s through 2009, including data from five peaks (Table 1). Results suggest an increasing trend in total vegetation cover, exposed rock and lichens, and a decrease in exposed organic soil. For example, total vegetation cover increased on average across all summits from 26.6% to 33.6% and 31.4% across the time periods examined, respectively. In this analysis, it is appropriate to examine the overall means by time period as repeated measures ANOVA revealed no significant "Year * Summit" interactions. The decrease in exposed organic soil can be explained both by the increase in vegetation and in exposed rock. Exposed organic soil is either colonized by plants or erodes away until nothing but bedrock is left.

The second repeated measures analysis compared available photopoints from 1999 and 2009 on eight peaks (Table 2). No significant changes were found in vegetation cover during this ten year

Table 1. Repeated measures analysis (n=19) of groundcover classes from three monitoring time periods across five Adirondack summits.

Cover Class [1]	Mean Cover (%) [2]			Year Effect [3]		Year*Summit [3]	
	1960s	1990s	2009	F	P	F	P
Grass	5.9	5.7	4.7	0.155	0.857	0.082	0.992
Forbs	3.0	3.6	3.9	0.452	0.641	1.93	0.125
Lichens	5.8 [a]	11.6 [b]	15.2 [b]	5.38	0.027	1.20	0.347
Mosses	1.3	3.8	4.1	3.13	0.074	1.92	0.135
Shrubs	5.3	6.4	7.1	0.789	0.403	0.464	0.781
Krummholtz	6.1	7.2	10.2	1.72	0.206	0.279	0.967
Trees	0.56	0.33	0.06	1.13	0.324	1.66	0.280
Mineral Soil	1.9	2.2	0.46	2.32	0.116	1.06	0.415
Organic Soil	18.1 [b]	4.1 [a]	4.5 [a]	20.6	0.000	2.55	0.082
Exposed Rock	24.2	33.3	30.5	4.22	0.039	1.75	0.159
Gravel	5.1 [c]	1.7 [a,b]	1.4 [b]	6.52	0.019	1.70	0.195
Total Vegetation Cover	26.6 [a]	33.6 [b]	31.4 [a,b]	4.18	0.043	1.60	0.20

Notes:
1. Summits included in this analysis are Algonquin, Cascade, Colden, Dix and Gothics.
2. In cases with a significant year effect, means followed by the same letter are not significantly different, P< 0.05.
3. Greenhouse-Geisser correction used throughout to correct for lack of sphericity in the data.

Table 2. Repeated measures analysis (n=31) of groundcover classes from two monitoring time periods across eight Adirondack summits.

Cover Class [1]	Cover (%)		Year Effect [2]		Year*Summit [2]	
	1999	2009	F	P	F	P
Grass	14.0	13.5	0.061	0.807	0.595	0.753
Forbs	2.7	3.6	4.25	0.051	1.82	0.128
Lichens	6.9	9.7	3.18	0.087	1.79	0.138
Mosses	4.5	4.74	1.03	0.320	2.01	0.098
Shrubs	8.1	8.3	1.37	0.252	1.74	0.148
Krummholtz	4.8	6.5	9.69	0.005	2.36	0.057
Trees	0.68	0.52	22.3	0.000	12.4	0.000
Mineral Soil	2.5	1.4	10.2	0.004	1.62	0.179
Organic Soil	3.3	2.5	0.663	0.424	0.892	0.528
Exposed Rock	22.4	18.9	5.40	0.029	2.33	0.059
Gravel	1.3	1.7	1.65	0.211	1.02	0.440
Total Vegetation Cover	41.8	44.5	2.94	0.100	0.643	0.716

Notes:
1. Summits included in this analysis are Algonquin, Cascade, Colden, Dix, Marcy, Skylight, Whiteface, and Wright.
2. Greenhouse-Geisser correction used throughout to correct for lack of sphericity in the data.

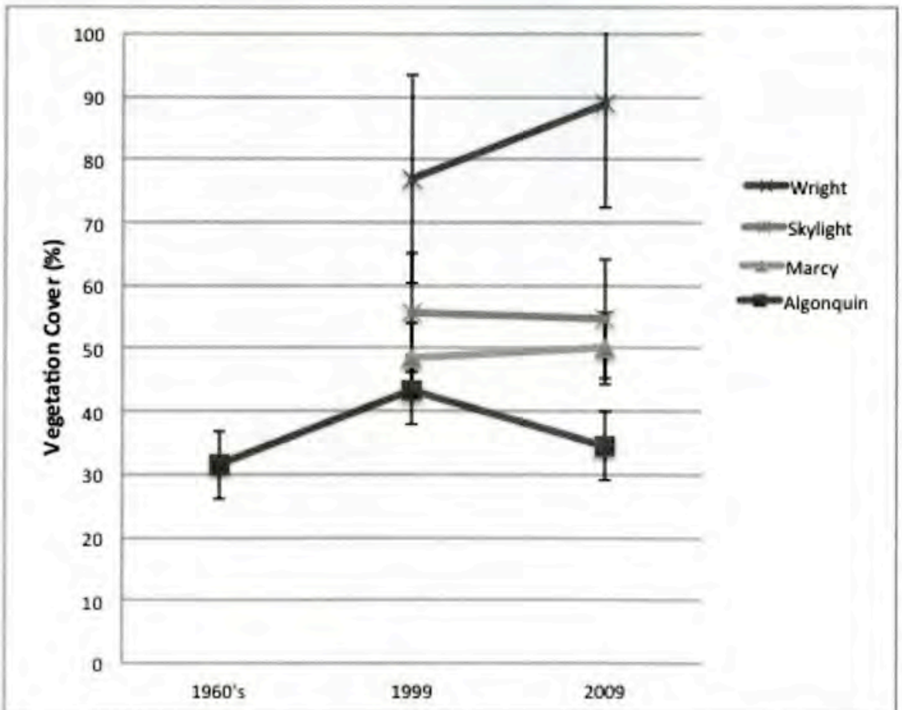

Figure 3. Summits with a consistent stewardship presence. Values are means ± one SD.

period, while exposed rock decreased during this period from an overall mean of 22.4% in 1999 to 18.8% in 2009. Forbs, lichen, moss, krummholz, and trees all increased, possibly explaining the decrease in exposed rock. Krummholz vegetation increased modestly, from 4.8% to 6.5% and trees showed a significant change, although the total proportion in the images is so slight, it is unlikely that this change is meaningful. Once again, few "Year*Summit" interactions were observed.

A descriptive examination of trends across particular summits of interest (Figures 3, 4, and 5) depicts changes in total vegetation cover over time. On summits with a consistent stewardship presence (Figure 3) findings suggest that vegetation at photo points is unchanged on the summits of Mt. Marcy and Skylight, with some possible trends of increasing cover on Wright Peak and Algonquin. On summits without a consistent stewardship presence (Figure 4), trends point to slight decreases in overall vegetation cover, while on remote summits, with low visitation (Figure 5), trends suggest an increase in vegetation at photo points. It should be noted that changes observed are not statistically significant but are presented to show overall trends over time. Additionally, it should be noted that there are differences in visitation numbers, biotic, and abiotic factors among the summits which complicate the comparisons across summits.

Discussion

Alpine ecosystems are a distinctive feature of the Northern Forest region. These areas contain vegetation found nowhere else in the Northeastern US and are home to some of the region's greatest recreational opportunities. Trampling disturbance poses a serious threat to fragile alpine vegetation; thus, management and monitoring of the heavily used summit areas is critical. For ten years the Adirondack High Peaks Summit Steward program has utilized photopoint monitoring to document changes in alpine vegetation with

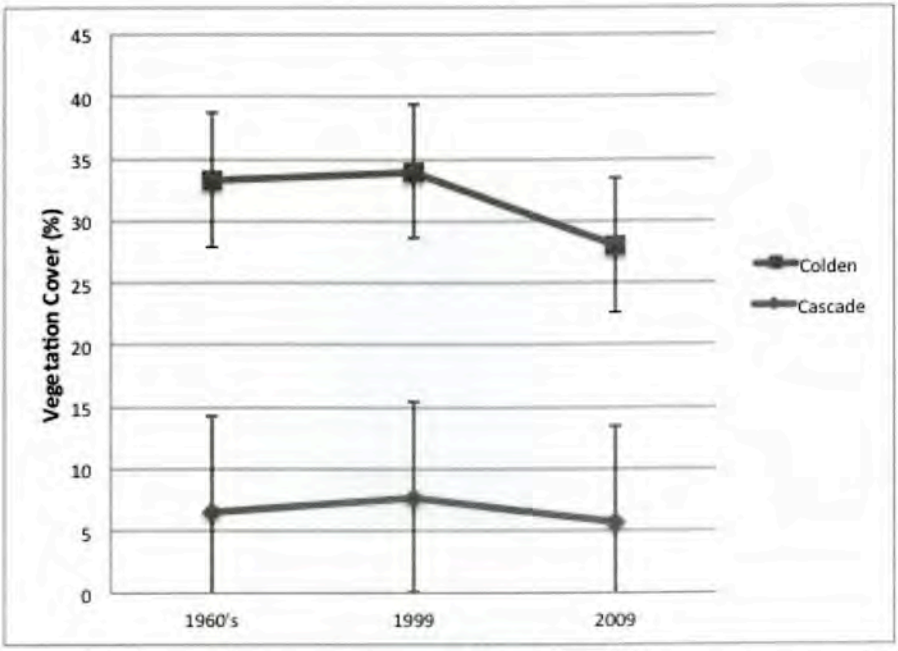

Figure 4. Summits without a consistent stewardship presence. Values are means ± one SD.

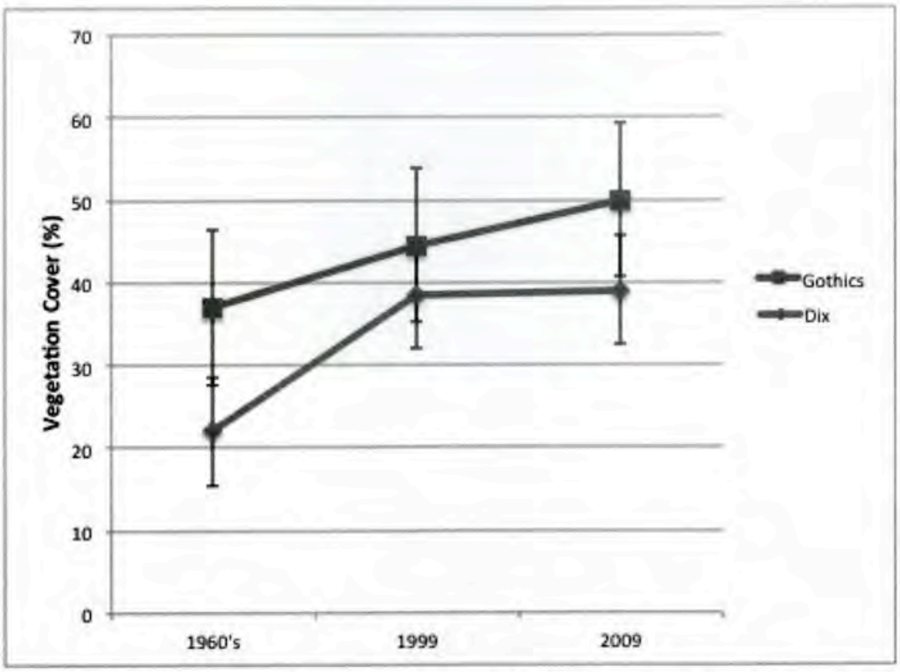

Figure 5. Trends on remote, low visitation summits. Values are means ± one SD.

a particular focus on areas subject to human trampling.

Since the creation of the Summit Steward Program in 1989, stewards have provided coverage 4505 days on New York's alpine peaks. During that time, stewards have interacted with over 307,000 hikers (Goren, 2011). Over 94% of the total coverage provided by Summit Stewards has been on Marcy, Algonquin, Wright, Skylight, Gothics, and Dix. Of these, Mt. Marcy and Algonquin have received the overwhelming majority of steward coverage. This is a logical management emphasis, as Marcy and Algonquin combined have 33.8 hectares of alpine habitat, or approximately 50% of the alpine ecosystem in the state (Howard, 2009). More significantly, Marcy and Algonquin receive the highest numbers of visitors, including many first time hikers (Giglinto, 2011, personal communication). Stewards have educated 277,593 hikers on these two peaks alone. With such a high volume of visitor contact and annual visitation increasing over time, the maintenance of a relatively constant and even increasing level of ground cover on Marcy and Algonquin suggests that the direct education and conservation projects, such as scree wall construction, completed by Summit Stewards are effective in promoting alpine maintenance and recovery.

This study assessed historical and contemporary photo points to examine whether long term trends in vegetation cover could be determined and the efficacy of a management intervention to minimize trampling disturbance could be determined. Based on the data presented and our overall experience with this study, several conclusions, limitations and suggestions for future monitoring are warranted.

First, our method of applying an image analysis procedure to both historical and contemporary oblique monitoring images does allow for a degree of comparative quantitative analysis that would not be possible otherwise. The close range nature of the photos provides considerable detail as has been demonstrated in other work (i.e., Booth et al., 2005) and was successful in the comparative analysis done in this study. The challenge lies in the more subtle interpretation of these results, in that changes in vegetation cover could be the result of increased vertical growth as well as horizontal spread. Evaluating the areal extent of vegetation cover is likely the more important aspect to understand trampling impacts, and so in this case the study is limited.

Second, we conclude, based on the repeated measures analysis, that the photo monitoring points have shown some changes over time. In most cases, these changes have resulted in increases in vegetation cover (both total and certain cover classes) that could be associated with successful management of recreation and limiting trampling disturbance. Other changes, such as the increase in exposed rock observed in the longer term photos (Table 1) would suggest an increase in disturbance, but this trend is not consistent in the 1999-2009 comparison (Table 2), so it is difficult to interpret. We emphasize that the results here are highly purposive and they may not apply to the entire summit areas.

The presence of a Summit Steward makes a difference in the recovery rate of vegetation in alpine areas. Areas with high visitation and regular steward presence show signs of recovery, while areas with high visitation and irregular steward presence show signs of continued damage.

Last, descriptive trend analysis of individual summit areas (Figures 3, 4, and 5) is consistent with the findings of the statistical analysis, i.e., a general trend of maintaining or increasing vegetation cover on summits with a Summit Steward presence or where the level of remoteness is likely to result in a self selection of visitors who are well versed in minimum impact practices on mountain summits.

Conclusions

Image analysis methods able to extract quantitative data provide a promising technique to advance monitoring and evaluation of management techniques. This study utilized oblique images to evaluate trends in the recovery of alpine vegetation in the Adirondack High Peaks Wilderness and to examine the effectiveness of the Summit Steward program.

The results suggest that the presence of a Summit Steward makes a difference in the recovery rate of vegetation in alpine areas. Areas with high visitation and regular steward presence show signs of recovery, while areas with high visitation and irregular steward presence show signs of continued damage. Other factors such as hiker experience level, conservation projects, and abiotic factors such as slope and seasonal moisture fluctuations may also have influenced the data presented. Findings strongly suggest the need for further research using a controlled design to analyze these different factors and to be generalizable to the summit areas and the region as a whole. The results presented are encouraging, however, as they suggest that the Summit Steward program, with its integration of management techniques and education, is accomplishing its goal of protecting New York's alpine ecosystem.

Acknowledgements

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References

Bennett, L. T., T. S. Judd, M. A. Adams. 2000. Close-range vertical photography for measuring cover changes in perennial grasslands. *Journal of Range Management* 53: 634–641.

Booth, D. T., S. E. Cox, M. Louhaichi, D. E. Johnson. 2004. Lightweight camera stand for close-to-earth remote sensing. *Journal of Range Management* 57: 675–678.

Booth, D. T., S. E. Cox, C. Fifield, M. Phillips, N. Williamson. 2005. Image analysis compared with other methods for measuring ground cover. *Arid Land Research and Management* 19: 91–100.

Brewer, L. and D. Berrier. 1984. Photographic Techniques for monitoring resource change at backcountry sites. General Technical Report NE-86. Broomall PA: US Department of Agriculture Forest Service, Northeastern Forest Experiment Station.

Cole, D. N. and V. Wright. 2003. Wilderness visitors and recreation impacts: baseline data available for twentieth century conditions. RMRS-GTR-117. Ogden, UT: USDA Forest Service, Rocky Mountain Research Station.

Doucette, J. E. and K. D. Kimball. 1989. Franconia Ridge Trail Study: The efficacy of scree walls for protecting alpine habitat AMC Technical Report 90-3. Gorham, NH: Research Department, Appalachian Mountain Club.

Goren, J. 2011. Summit Steward Program End of Season Report. Adirondack Mountain Club.

Hammitt, W. E. and D. N. Cole. 1998. *Wildland Recreation: Ecology and Management. Second Edition*. New York: John Wiley.

Howard, T. 2009. Vegetation Communities of the Adirondack Alpine Zone. New York Natural Heritage Program. Unpublished report.

Ketchledge, E. H., R. E. Leonard, N. A. Richards, P. F. Craul, A. R. Eschner. 1985. Rehabilitation of Alpine Vegetation in the Adirondack Mountains of New York State. Research Paper NE-553. Upper Darby, PA.: USDA Forest Service, Northeastern Forest Experiment Station.

Leung, Y-F. and C. A. Monz. 2006. Visitor Impact Monitoring: What, Why, and How? *George Wright Forum* 23(2): 7-10.

Lillesand, T. M., R. W. Kiefer, J. W. Chipman. 2007. Remote Sensing and Image Interpretation. Sixth Edition. New York: John Wiley.

Marion, J. L. 1995. Capabilities and management utility of recreation impact monitoring programs. *Environmental Management* 19(5): 763-771.

Monz, C. A. and P. D. D'Luhosch. 2010. A simplified image analysis method for monitoring wilderness campsites. *International Journal of Wilderness* 16(1): 26-31

Monz, C. A., J. L. Marion, K. A. Goonan, R. E. Manning, J. Wimpey, C. Carr. 2010. Assessment and monitoring of recreation impacts and resource conditions on mountain summits: Examples from the Northern Forest, USA. *Mountain Research and Development* 30(4), in press.

Redmond, P. G. Protecting the Islands in the Sky: Lessons From Conserving the High Alpine Communities. *Adirondack Journal of Environmental Studies*, Spring/Summer 1997.

Scott, M. 1999. Summit Steward Report for Photomonitoring. The Nature Conservancy.

Young, S. M., and T. W. Weldy. 2006. New York Rare Plant Status Lists, May 2006. New York Natural Heritage Program.

Appendix: Examples of Photopoint Comparisons

Figure A1. Photopoint comparison, Mt. Marcy summit, 1992 (left) vs. 2009 (right)

Figure A2. Photopoint comparison, Mt. Marcy summit, 1981 (left) vs. 2008 (right)

Figure A3. Photopoint comparison, Cascade Mountain summit, 1966 (left) vs. 2009 (right)